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Coping with Uncertainty: An Expedition into the Field of New Transport Technology

van Geenhuizen, M.; Nijkamp, P.

published in

Transportation Planning & Technology
2003

DOI (link to publisher)

[10.1080/0308106032000167355](https://doi.org/10.1080/0308106032000167355)

document version

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

citation for published version (APA)

van Geenhuizen, M., & Nijkamp, P. (2003). Coping with Uncertainty: An Expedition into the Field of New Transport Technology. *Transportation Planning & Technology*, 26(6), 449-467.
<https://doi.org/10.1080/0308106032000167355>

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COPING WITH UNCERTAINTY: AN EXPEDITION INTO THE FIELD OF NEW TRANSPORT TECHNOLOGY

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(Received 22 March 2001; Revised 9 August 2003; In final form 10 October 2003)

Many decisions taken by mankind are rational only to a limited extent. This holds for individual travel behaviour, but also for long-range strategic decisions on transport systems or transport technology. In any decision problem, coping with uncertainty is the most critical element. The introduction of new transport technology is surrounded by uncertainty. For example, there is uncertainty about the pace and extent of adoption of new technology and there is uncertainty about the impact of new technology in terms of increased sustainability or increased efficiency. This article maps uncertainty surrounding new transport technology and identifies ways in which to deal with uncertainty in policy making. The findings will be illustrated with electric vehicles, particularly with two specific strategies to deal with uncertainty: interactive technology watching and experimentation in a market niche. The paper concludes with a discussion of success factors that influence the outcomes of such strategies.

Keywords: New transport technology; Electric vehicles; Uncertainty; Policy making; Technology watching; Innovation agent

1. HOMO MOBILIS AND HOMO ECONOMICUS

Conventional wisdom in transport science suggests that transport movements serve to overcome physical distance barriers. Such movements are – apart from a few rare cases like leisure trips without a destination – necessary because of the geographical separation of

various activities (residential, employment, social, etc.). Since transport is regarded as a burden, the rational decision-making paradigm then suggests that it is wise to minimize the transport effort. In particular, welfare theory – one of the corner stones of transport economics – argues that it is in the interest of the ‘homo economicus’ to minimize travel costs (pecuniary, time-wise or psychological).

This assumption lies at the basis of many utility-based demand studies (e.g. discrete choice models) but has also created the foundation of many aggregate transport studies (such as quadratic assignment models, linear programming models for modal split or route choice and the like). The overwhelming majority of transport studies consider physical movement as a sacrifice. If this basic assumption were valid, then a series of intricate and intriguing questions emerges. How is it that the action radius of modern human beings tends to increase structurally [1]? How is it possible that the ‘law of conservation of travel time’ is rather robust (at least in metropolitan areas), but shows an increasing trend for longer trips? Is the modern ‘homo mobilis’ essentially a ‘homo economicus’ or are we driven by other – also rational – instincts?

In a recent study on ‘slow motion’ [2] a review of motives in favour of other – less fast and (perhaps) more environmentally benign – modes of transport was given, based on the recently developed concept of a ‘time pioneer’. The argument is that it may – from both an individual and a collective welfare perspective – be rational to reduce travel speed. Empirical research however, demonstrated that the willingness among travellers to choose ‘slow motion’ options is disappointingly low. On the contrary, the trend is towards more speed and a larger action radius. Does this mean that the ‘homo mobilis’ is not a rational decision-maker? It should be noted that the basic hypothesis in welfare theory is that individuals seek to maximize their own welfare, based on the assumption of perfect information and on the absence of externalities, bandwagon and image effects, and the like. There is quite a literature, in particular in 1960s geography, which demonstrates convincingly – both conceptually and empirically – that the choice of the actual location of firms can differ significantly from the theoretical optimal location [3]. This is then explained by the prohibitive role of high search costs to find the optimum optimum. Decision-makers often tend to be satisfied with a second-best – or even third-best – location, as they are not driven by the exclusive goals of profit seeking behaviour. The theoretical basis of this ‘satisficing’

behaviour has been given by Herbert Simon in this theory of 'bounded rationality' [4].

Apart from the costs involved in gathering perfect information, there is also a social driving force. Location and travel decisions are not taken in a Robinson-Crusoe economy on an isolated island, but in social interaction with others (the notion of the 'homo socialis'). For example, the need to live near one's relatives may lead to a residential location decision that is not optimal from a cost-minimizing viewpoint. Consequently, there is some evidence that travel decisions are not exclusively governed by rational – cost-minimizing, utility-maximizing or profit-maximizing – behaviour. Theoretically speaking, this would imply a specification bias in many of our behaviour transport models. In any case, the 'homo mobilis' is faced with many uncertainties in his/her travel choices; perfect information is an illusion. This recognition may have serious implications for the precise value of transport models and limits seriously the scope of cybernetics oriented engineering approaches in transport science.

There is still another issue. To assemble proper information may be too costly, but the human ability to digest all relevant information is also limited. Consequently, the available or existing information may also be selective and has to be interpreted from the subjective perspective of the user or decision-maker. Furthermore, if travel information has to be transmitted to road users, the question is whether a particular road user needs exactly the given information. In many cases, they may be willing to receive additional or other information. This is clearly reflected in an early statement of March and Simon: '... the vast bulk of our knowledge of fact is not gained through direct perception but through the second-hand, third-hand, and n th-hand reports of the perceptions of others, transmitted through the channels of social communication. Since these perceptions have already been filtered by one or more communicators, most of whom have frames of reference similar to our own, the reports are generally consonant without the filtered reports of our own perceptions, and serve to reinforce the latter' [5: 153].

The previous remarks do not only apply to daily or routine decisions. They are equally relevant for strategic decisions of a long-range nature on transport systems or transport technology. Coping with uncertainty is essentially the most critical element in any decision problem. This question extends far beyond stochastic or probabilistic approaches to uncertainty management.

2. EXPLORING THE FUTURE

In the past decades we have observed a great variety of attempts to come to grips with an uncertain future. This is clearly exemplified by the path breaking work of Kahn and Wiener on *The Year 2000*, published in 1967 [6]. The question is whether much progress has been made in the past decades. This provokes in particular a complicated methodological issue, as it asks whether better understanding does also lead to better forecasting. Some remarks on this issue are in order. Explanation is a process of logical deduction and empirical validation, in particular in the context of repetitive events. In a strict sense it would be impossible to subject 'unique' events to a scientific explanation. In any case, an explanation in a probabilistic statement of an 'if-then' nature, which – given a predetermined domain – is able to make a scientifically founded statement on the possible or probabilistic occurrence of events as part of or as a result of events that fall outside the a priori defined domain. Thus, an explanation has a number of restrictions and its validity is limited by prior hypotheses and by methodological constraints.

From a methodological perspective there is little distinction between explanation and forecasting, apart from an obvious difference between prospective and retrospective thinking. However, forecasting is also a process of logical analysis on the basis of empirically verifiable relationships, with the only exception being exogenous variables – falling outside of the forecasting domain – that cannot be observed empirically, but can at least be hypothesized (e.g. on the basis of plausible reasoning). But in principle one might argue that forecasting and explanation are the same thing.

In the history of future studies we may distinguish various approaches which aim to offer a scientific underpinning for statements on future events. Examples are the following:

- *Blueprint thinking*. In this mode of thinking the basic assumption is that it is possible to define a feasible amount of targets in the future, which can be realised through the right use of instruments. The idea of a 'makeable' society – very popular in the 1970s and 1980s – is illustrative of this approach.
- *Normative thinking*. Here the idea is that a society may evolve according to a priori fixed, normative – sometimes ethical – criteria. The development of a classless society or a society with equal opportunities for each member are examples.

- *Nested thinking*. This is based on the conviction that the future as a whole is difficult to forecast, but that certain parts or aspects (e.g. demography, technology) may be mapped out with sufficient accuracy.
- *Fiction thinking*. This type of future thinking is based on a non-historical approach and questions the limits posed by past constraints.
- *Scenario thinking*. This has become a popular way of analysing the future. It presupposes the design or existence of meaningful – not necessarily realistic – future images, but it demands that such images meet strict methodological requirements such as internal consistency and a bridging between the present and the future. Such scenarios are politically not committing, but offer a spectrum of future developments [7,8].
- *Evolutionary thinking*. This approach is not based on normative or policy views, but assumes some sort of adjustment mechanism in human behaviour (e.g. resilience), which drives living organisms or systems towards ‘continuity in change’. It also draws attention to a phenomenon named path dependency, meaning that future moves in policy making are constrained by decisions made in the past.
- *Learning thinking*. This mode of thinking has a long history [9] but has recently become fashionable in connection with evolutionary thinking. Popular concepts in this framework are the learning decision-maker, the learning organization, the learning city, etc. This principle forms a contrast with blueprint and normative thinking and avoids ‘linear’ thinking. It is based on a blend of positive and negative feedback responses in a dynamic choice environment [10].

The above observations hold also for the future acceptance of new transport technology. The high risks of new technologies may hamper their rapid introduction but the acceptance attitude of the user may also cause a stumbling block. These issues are discussed further in the next sections.

3. THE UNCERTAIN ROADS OF TRANSPORT SYSTEMS

Transport is the spatial projection of societal dynamics. The 21st century will see a variety of new social and technological trends which will influence the way in which transport is supplied and utilised [11]. At present a wide range of social phenomena, including rising incomes, increased leisure time, new communication technologies, an

ageing population and a declining role for the traditional family, are changing the nature of the demands we place on transport. In response to new techniques of production, shipping and the growth of markets, economic activities are also changing. Institutional reforms such as privatization and deregulation have changed transport in ways that are not yet well understood. At the same time increasing use of petroleum resources for travel and transport has raised concerns about the eventual depletion of fossil fuels as well as its contribution to global warming and decreases in urban air quality. These developments force us to ask ourselves: do we have the scientific apparatus to forecast uncertain future developments, trends or events, particularly those that are crucial in the adoption of new transport technology?

New technology may affect the transport system in two different ways. First, there is *optimization* of the current transport system by using existing potentials, and second, there is the much more comprehensive *structural change* of the transport system. A good example of the first is the electric vehicle (EV) in that the concept of individual cars remains unaffected in merely challenging the type of traction system. However, if electric vehicles are used in new concepts of carpooling and mixed forms of private and public transport (using, for example, buses) attention moves to structural changes in the transport system [12]. Accordingly, the latter case involves much more uncertainty.

Uncertainty can be tackled from various angles. For example, Rowe [13], in elaborating uncertainty as the 'absence of information', makes a division into various dimensions [14]:

- *Temporal* uncertainty. This refers to the future state of the transport system (prediction uncertainty) and related systems, but also to the past states of these systems.
- *Structural* uncertainty. This refers to the complexity of the transport system in modelling. Structural uncertainty depends on the number of parameters and interaction used in models to describe a situation or development. The key question is how well the models represent reality.
- *Metrical* uncertainty. This is concerned with difficulties in measurement of the system. Central issues here are precision and accuracy (validity). Such uncertainty plays a role, for example, in measuring preferences of travellers regarding public transport.
- *Translational* uncertainty. This refers to the communication of the results of analysis and modelling in a policy context. Goals and

values of the stakeholders are the main issue because these affect the interpretation of the results and the related effort in consensus building.

All four dimensions of uncertainty occur in any situation and reinforce each other. The last dimension – translational uncertainty – indicates the importance of stakeholders in policy making, such as interest groups, governments, car manufacturers, shippers and transport infrastructure contractors. The interests of such stakeholders may be different, dependent upon their goals and means, problem perception and interpretations. An interesting example in this framework is the estimation of future traffic flow and the estimation of costs of large transport projects [15]. A compilation of before-and-after-studies of various large transport infrastructure projects shows considerable cost overruns (of 50–100%) and traffic forecasts that are remarkably optimistic (by 20–60%). The differences between forecast and actual costs and traffic cannot be explained primarily by structural uncertainty. By being strongly consistent and one-sided the uncertainty that has entered is much more of the translational type and needs to be seen – as Wynne [16] puts it – as a ‘social construct’.

By adopting the perspective of policy making and by conceptualizing the relevant part of reality as a system, four classes of uncertainty can be distinguished. First and foremost, there is uncertainty about the future *outcomes* of the system, given a set of uncontrollable inputs to the system and given uncertainty about the reaction of the system on both controllable and uncontrollable inputs. Second, there is uncertainty about the future behaviour of *external influences* that causes the uncontrollable inputs to the system. What we mean here are influences like global economic growth, consumer preferences, and measures in adjacent policy fields, like spatial planning and taxation. Uncertainty about *system behaviour*, connected with the way the system reacts to various inputs, is a third class. The causes here are a lack of adequate theory about system behaviour and consequently a poor modelling, as well as problems with specification of empirical values. We finally may distinguish uncertainty in the *selection of policy measures*. This uncertainty follows from the previous ones. A further cause is a lack of guiding values in policy making, i.e. values on a more general level that gives a particular direction to policy measures. An example is the potential right of car drivers to perform drivers’ functions independently from central systems.

This classification serves as a framework in our identification of

uncertainty in policy making on the adoption of electric vehicles in the next section.

4. POLICY MAKING CONCERNING ELECTRIC VEHICLES

The development of electric vehicle technology during the end of the 19th and beginning of the 20th centuries exemplifies highly dynamic processes with unexpected outcomes [17,18]. At the start of the market introduction at that time, electric cars were far ahead compared with cars powered by the internal combustion engine (ICE). The ICE was considered to be inferior because of the noise it produced, and its unsafe and dirty character. There was also a need for some additional but complicated technical innovations. However, the strategic behaviour of a few ICE-powered car producers – especially their move to a mass market and use of innovative marketing tools – has given the ICE-powered car a dominant position. Due to subsequent advantages from increasing returns to scale (and lock-in), the ICE-powered car could maintain this position whereas competing technologies faced progressively greater difficulty in entering or surviving in the market. This example shows the unpredictability of the winning technology – connected with various small events (or actions) – and the non-superiority of the selected path.

A detailed analysis of the adoption of electric vehicles as it is today and of concomitant policy making brings a differentiated 'landscape of uncertainty' to light [12,19,20]. The key uncertainty belongs to the behaviour of the system, i.e. user acceptance, and to the future outcomes of the system (Table I). Accordingly, it is difficult to select the appropriate policy measures. In fact, we are not able to model user acceptance behaviour and policy impacts in such a way that it helps to predict the adoption of electric vehicles and to get insights into underlying factors. Metrical uncertainty, of course, contributes to the lack of adequate prediction results. For example, despite progress there are still some measurement problems to solve in studies focusing on stated preferences (of users) [21] and opinions (of experts) [20]. The uncertainty that stems from the *critical* user acceptance seems connected with performance aspects of electric vehicles, that is a relatively small range of battery charged vehicles, danger of dead battery during trips, and the relatively high price for buyers, but there seems more. Over the past decades cars have increased freedom, mobility, prestige and much more in the life of individuals [22]. It may

TABLE I Uncertainty in policy making for electric vehicles

<i>Element</i>	<i>Details</i>	<i>Strength of uncertainty</i>
Future outcomes	<ul style="list-style-type: none"> — Achieving target results of adoption — Causing negative side-effects 	Strong Strong
External influences	<ul style="list-style-type: none"> — Behaviour of actors in dominant technologies (resistance from lock-in), such as conventional car manufacturers and fuelling industries — Growth of customer segments with large opportunities (second cars, business cars) 	Weak Weak
System behaviour	<ul style="list-style-type: none"> — The time that high performance batteries and fuel cells are available at a competitive price — Divides within the technology, such as low and high temperature battery systems, leading to potential incompatibilities — Critical user acceptance: willingness to pay extra and bear inconvenience for environmental gains; willingness to "lose freedom or independence" in a shift to non-private transport 	Weak Weak Weak
Selection of policy measures	<ul style="list-style-type: none"> — Effectiveness of measures, e.g. of incentives, subsidies — Missing guiding values 	Strong Weak/strong

take, therefore, a number of years to add the totally different environmental ideals, such as to clean the air and reduce noise, to this range. Moreover, electric cars may never attract drivers that are moved by car appeal going far beyond merely functional transport. Knowledge of such appeals and their influence is too small to date in order to contribute to sound predictions. The same holds for uncertainty in the case of mixed private–public transport using electric buses. Here, we may expect user resistance based on a general aversion against all modes that are different from the individually used car. On the other hand, environmental motives may become strong in the segment of second (or additional) cars in households and in the segment of business users. Both are growth markets, and we may be able to predict how fast these segments will grow in the coming years.

Uncertainty in future outcomes of the system can be summarized as follows. Due to uncertain system behaviour and uncertain inputs, the latter mainly from external factors, we are not able to predict the outcomes of the system in terms of a move towards reaching policy aims, such as sustainable energy aims and prevention of externalities (e.g. noise, emissions, etc.). The same holds for adverse effects, such as an increase in overall car mobility, due to the use of electric cars as second (or additional) cars in households. Buying electric cars may serve as a kind of justification, whereas without a pushing policy of electric cars no second or third cars would have been bought.

As far as technology is concerned, uncertainty seems far less strong. Battery and fuel cell technology will need some five more years before these can be used in high performance and cost competitive electric vehicles. Research on improved performance and reduction of production costs of light-weight rechargeable solid-state lithium-ion batteries is of particular interest. Research focuses on the stability, compatibility and electrical properties of the battery components. World-wide research also focuses on cost reduction of polymer fuel cells, among others by reducing the amount of platinum catalyst. The uncertainty that is involved seems to be ‘manageable’ in that it can be reduced by increased research and development efforts [19].

Further, in terms of *guiding values*, an important missing link in policy making to date is a clear vision of the functions of transport, other than the straightforward bridging of distance. These other functions may be strongly (social) psychological, like a gain of individual freedom, increase of power, and gain of identity. In a situation in which it is generally accepted that car driving only serves the functional bridging of distance, designing a policy to enhance the adoption

of electric vehicles is less difficult compared with a situation without such a guiding value.

The above circumstances indicate significant uncertainty in the selection of policy measures to enhance the adoption of electric vehicles. The ways in which policy makers may deal with uncertainty is discussed in the next section.

5. STRATEGIES TO COPE WITH UNCERTAINTY

There are many strategies for coping with uncertainty, each using different methods. The following strategies can be distinguished [14, 23–25]:

- To *ignore* uncertainty, take policy measures, and see what will happen. While this may be the easiest option for the short term, it means accepting large uncertainty with respect to the policy outcomes and a fair chance for major disasters, i.e. solutions that are virtually obsolete by the time that they come into operation.
- To *identify* and, if possible, *specify* uncertainty. This enables the policy maker to act consciously in the presence of uncertainty. The classifications above may be helpful in this respect. Methods to identify and specify uncertainties include scenario analysis (e.g. for uncertainty in the system's surroundings) [7,26,27], exploration of 'weak signals', development of alternative system models to account for alternative structures, and determination of confidence bounds for data and model parameters.
- To *do nothing* and let uncertainty be reduced by time; this approach means delay, and involves a good chance that, while some uncertainties will disappear, new ones will emerge. Doing nothing may be a positive choice, based on a vision in which the self-organizing capacity of society and particular interest groups is given priority and is trusted to achieve satisfactory outcomes.
- To *reduce* uncertainty. This can be done in different ways. First, by additional research or better integration of existing knowledge; this might cover the range from the collection of new data to the application of advanced methods of integrated modelling and explorative modelling to more clearly distinguish between possible and impossible developments, and to identify critical events and bottlenecks. Second, by pushing the uncertainty onto someone else, which generally will involve costs (e.g. insurance premiums,

compensation). Third, by negotiating with others whose behaviour is uncertain but has a significant impact on the desired policy outcomes. This may involve processes of participatory policy development, and/or agreements with policy makers in adjacent fields.

- To *accept* uncertainty, and *act consciously* in its presence. Here, too, different strategies are possible. A robust policy may be selected, that is a policy that will do well in most possible future circumstances. Or a flexible policy is designed, a policy that is adaptable to the future course of events [28].
- To see uncertainty not as a threat, but rather as an *opportunity* to shape the future creatively. Rather than emphasizing a choice for a presently available policy option, this approach calls for development of a vision that provides the guiding principles for present and future action, such as experiments reflecting stakeholders' interests and other learning exercises that may underpin policy measures [10].

It seems self-evident that the above strategies do not exclude but often complement each other [29]. We now turn to two complementary roles that may be adopted by national governments in an attempt to identify and specify uncertainty, and learn about the future by experimentation, that is the role of technology watcher and the role of innovation agent [12,30].

6. ROLE OF TECHNOLOGY WATCHER AND INNOVATION AGENT

The exploration of roles of national governments in coping with uncertainty in this section is based on experiences gained in The Netherlands. The role of *technology watcher* includes a systematic monitoring of technological developments and understanding of these developments in terms of repercussions for policy. The developments are positioned as layers that provide the appropriate background to assess the relevance of the new technology in transport. These layers include the one of components (such as batteries and fuel cells in the case of electric vehicles), the application (e.g. concepts of propulsion), the type of vehicle (cars, buses), the transport concept (short or long distance transport), and the transport system (such as multi-modal

commuter transport systems). The main activities of technology watching are:

- (1) to collect useful information on a particular technology and its potential markets;
- (2) to arrive at a broad interpretation of this information leading to score matrices for the technology based on specific criteria;
- (3) to establish various rounds of interaction with policy makers, policy analysts and researchers in order to focus on policy relevance;
- (4) to establish a synthesis and preliminary conclusions;
- (5) to distribute the results to policy makers and other stakeholders.

What is new in this approach is the acknowledgement that each of the above activities includes a number of *choices*, for which a solid and transparent argumentation needs to be provided preferably in interaction with important stakeholders. Apart from the selection of the technology itself, there is for example the selection of the type of information to be collected (activity 1) and the criteria to be used in a first interpretation (activity 2). The key activity of course is to scan the technology for *policy relevance* (activity 3), including both an assessment of direct impacts and an exploration of (potential) use of the technology according to various criteria. The latter activities may encompass various rounds of scenario analysis in order to learn about the technology. In terms of results, the methodology may not only clarify the potential role of the technology but also the role of factors that advance or prohibit this role.

It is increasingly acknowledged that a *participatory* (or *interactive*) structure is a key prerequisite for success of the methodology. This means a continuous input from the side of independent experts and users of the technology at hand. There is a trend to consider a *broad* group of stakeholders as relevant, that is also including actors on the supply side of the new technology, like manufacturers and sponsors, and organizations that contribute to the embedding of the technology [30]. This broad input serves to cover the perspectives of all influential players at hand and, accordingly, to increase support of them. However there is also a danger here. It may happen that results are achieved without sufficient reflection of real-life power structures, thus being unrealistic in a sense. This calls for a delicate design of participation to arrive at strong outcomes that have sufficient 'authority'.

In the role of *innovation agent* the government is actively involved in a successful implementation of the new technology. One way of doing this is to experiment in a relatively small and protected niche of the market, and this is exactly the policy for electric vehicles in The Netherlands. A major experiment in the recent past dealt with daily commuting between the cities of Rotterdam and Zoetermeer, in which electric buses were used to bring commuters to work at the Ministry of Transport and Waterworks in Rotterdam. Such an experiment served various important goals, like to demonstrate the use of the technology and to test the technology on user value and acceptance. Technology experiments in niches like this one require the identification of the right market niche, a smart combination of resources and the involvement and interaction of the right stakeholders. More importantly, network management is involved in terms of shaping and reshaping the relationships between stakeholders [31]. The ultimate goal of such experimental small-scale implementation is to proceed with the adoption itself, while learning about advancing and hampering factors. The outcomes then serve as input for a further development and testing. Learning experiments like these match with a planning culture that is relatively new, vision-based planning (Fig. 1).

An essential difference with conventional planning approaches is that there are no predetermined goals to be achieved by using new technology and no predetermined policy measures that serve the realisation of these goals. Rather, there is a broad vision on new technology and transport, and there is a continuous interaction (communication) with stakeholders. Information from these two sources provides the basis for conducting various experiments. Further, the learning derived from a series of experiments (trial and error) may arrive at a stage that enables it to underpin decision-making.

Similar to the previously discussed role of technology watching, the experiments need to be selected, designed and carried out in such a way that there is a broad coverage of causal factors as well as a broad support from stakeholders for the results, without losing sense of real-life power relations. (Note, however, that vision-based planning is an interesting alternative to conventional practices only in specific classes of uncertainty in policy making. It is not regarded here as an appropriate solution for uncertainty concerning large-scale infrastructure projects like high-speed rail connections and Maglev systems.)

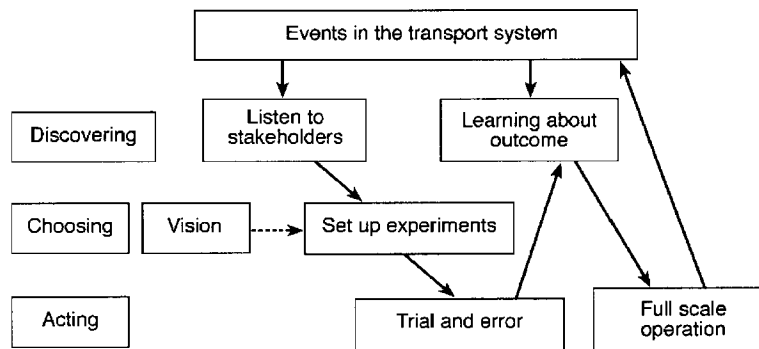


FIGURE 1 Vision-based planning.

7. VARIATIONS IN EUROPE

There are many different and contrasting national planning methodologies in use in Europe. For example, in some countries there is an emphasis on the input of users in technology assessment, whereas in other countries experts have a prominent role. The importance attached to reduction of uncertainty in policy making also varies from country to country, based on differences between national cultures [32–34].

What roles governments actually play with regard to promising transport technology is very much dependent upon a blend of factors. In policies for the introduction of electric vehicles in various European countries in the mid-1990s, we observe a diversity that can hardly be ascribed to differences in planning culture only [35–36] (Table II). Rather, various meso- and macro-economic factors seem to count. For example, The Netherlands compares well with Germany when considering the dominant type of electricity production. In both countries, electric vehicles using batteries would be powered with electricity from non-sustainable sources (coal and natural gas), a situation in which the environmental gains of the technology can be questioned and the public image of electric vehicles seems relatively weak. (Note that this might change if hydrogen powered fuel cells are used.) Other important factors that differentiate between countries include price and availability of electricity, and the match of electric

TABLE II Factors in macro (meso) systems and government roles in EV adoption in the mid 1990s

<i>Country</i>	<i>Factors</i>	<i>Role of government</i>
France	<i>Advancing factors</i> Need for outlet for nuclear power Recognition of air pollution in cities as a severe problem Centralised government Industry monopoly and oligopoly	Subsidy for EV purchase Co-ordination of initiatives Funding of R&D
Sweden	<i>Advancing factors</i> EV matches environmental policy EV is nearly zero emission Low price of electricity	Support of R&D Support of demonstration and procurement programmes
Germany	<i>Prohibiting factors</i> Non-renewable energy as basis and full emission (coal firing) Decentralised government Fragmented electricity industry	<i>Modest role</i> (recently increasing)
The Netherlands	<i>Prohibiting factors</i> Non-renewable energy as basis and full emission (gas firing) Fragmented electricity industry but high co-operation	<i>Modest role</i> Support of R&D Support of experiments in niche (collective transport)
Switzerland	<i>Advancing factors</i> EV matches environmental policy EV is zero emission	Clean Air Act Co-ordination and subsidisation of pilot programmes Subsidy for EV purchase

vehicles with accepted problem situations such as the recognition of air pollution in cities as a severe problem and the recognition of environmental problems in general. Furthermore, the industry structure seems important with monopoly and oligopoly enabling a smooth involvement by national governments. There is one factor of which the influence is not quite clear, namely the structure of the government system itself. In Germany, a decentralized system would hamper consensus building on the need for adoption of the new technology, due to the involvement of different governments on a lower level. However, in the case of Switzerland a similar government structure would not have a hampering influence, most probably because the new technology is not questioned due to its zero emission character. The Swiss government also acts as a conditioning agent in

the establishment of a kind of 'clean air act'. According to this policy, a total of 200 000 electric vehicles are planned to be on the road in 2010, corresponding to about 8% of the number of cars in the country today [37].

8. CONCLUSION

Transport is a complex activity that touches upon many different human activities. As a result, policy making is subject to uncertainty, a situation that calls for a strong awareness in the design of policy measures. This article has mapped out the landscape of uncertainty in the adoption of new technology in transport. In addition, it has considered different ways in which to deal with uncertainty, in particular two new roles of the government in The Netherlands; technology watching and experimentation in niche markets to advance adoption. What seems to be crucial for the success of both strategies is the ability to create a shared sense of urgency among the relevant stakeholders in involving them in the interaction at hand. At the same time, the results need to mirror real-life power relationships between stakeholders. This serves not only a large coverage in terms of influences, but also a sufficient support for and 'authority' assigned to the results. The latter is clearly necessary because the results of this type of new strategies are often not fully exploited by decision-makers.

Moreover, one needs to be aware of the potential dynamics in external factors, meaning shifts over time in both stakeholders and upcoming new technologies. As we have seen in the early history of electric vehicles, small events may cause a leading position of inferior technology and a reinforcing of this position over time. The latter phenomenon would have two implications for technology watching by governments: to cover a relatively broad spectrum of technologies and to identify the above indicated small but potentially very important events.

References

- [1] Doren, Ch. van (1991) *A History of Knowledge* (Ballantine Books, New York).
- [2] Nijkamp, P. and Baaijens, S. (1999) 'Time pioneers and travel behaviour', *Growth and Change* **30**, 237–263.
- [3] Wolpert, J. (1964) 'The decision process in a spatial context', *Annals of the Association of American Geographers* **34**, 537–558.
- [4] Simon, H. (1952) 'A behavioural model of rational choice', *Quarterly Journal of Economics* **69**, 9–118.

- [5] March, J.G. and Simon, H.A. (1958) *Organizations* (Wiley, New York).
- [6] Kahn, H. and Wiener, A.J. (1967) *The Year 2000* (MacMillan, New York).
- [7] Nijkamp, P. and Geenhuizen, M. van (1997) 'European transport: challenges and opportunities for future research and policies', *Journal of Transport Geography* 5, 4–11.
- [8] Nijkamp, P., Rienstra, S. and Vleugel, J. (1998) *Transportation Planning and The Future* (John Wiley, Chichester/New York).
- [9] Harvey, D. (1967) Models of the evolution of spatial patterns in human geography. In: Chorley, R. J. and Haggett, P. (eds) *Models in Geography*, pp. 549–608 (Methuen, London).
- [10] Stacey, R.D. (1992) *Managing the Unknowable* (Jossey Bass, San Francisco).
- [11] Becker, H. (1997) *Social Impact Assessment* (UCL Press, London).
- [12] Rutten, B.J.C.M., Korver, W. and Elzen, B. (1998) 'The importance of monitoring technology and experimentation' (in Dutch), *Tijdschrift Vervoerswetenschap* 3, 191–211.
- [13] Rowe, W.D. (1994) 'Understanding Uncertainty', *Risk Analysis* 14, 743–750.
- [14] Geenhuizen, M. van, Nijkamp, P. and Zuylén, H. van (eds) (1998) *Limits to Predictability in Traffic and Transport* (AVV, Rotterdam).
- [15] Skamris, M.K. and Flyvbjerg, B. (1997) 'Inaccuracy of traffic forecasts and cost estimates on large transport projects', *Transport Policy* 4, 141–146.
- [16] Wynne, B. (1992) 'Uncertainty and environmental learning', *Global Environmental Change* 2, 111–127.
- [17] Isoard, S. (1996) 'The diffusion of energy technologies: the influence of increasing returns', *The IPTS Report* 10, 10–15.
- [18] Cowan, R. and Hultén, S. (1996) 'Escaping lock-in: the case of the electric vehicle', *Technological Forecasting and Social Change* 56, 61–79.
- [19] Geenhuizen, M. van and Schoonman, J. (1999) Sustainable transport technology: a policy view on the adoption of electric vehicles. In: *Proceedings of CONAT '99, The IXth International Conference* (Transilvania University Press, Brasov).
- [20] Mulder, K., Weijer, C. van de and Marchau, V. (1996) 'Prospects for external sources of vehicle propulsion. Results of a Delphi study', *Futures* 28, 919–945.
- [21] Golob, T., Brownstone, D., Bunch, D.S. and Kitamura, R. (1996) *Forecasting Electric Vehicle Ownership and Use in the California South Coast Air Basin* (Institute of Transportation Studies, Irvine, CA).
- [22] Marsh, P. and Collet, P. (1986) *Driving Passion. The Psychology of the Car* (Jonathan Cape, London).
- [23] Friend, J. and Hickling, A. (1997) *Planning under Pressure. The Strategic Choice Approach* (Butterworth-Heinemann, Oxford).
- [24] Neufville, R. de (2000) 'Dynamic strategic planning for technology policy', *International Journal of Technology Management* 19, 225–245.
- [25] Geenhuizen, M. van and Thissen, W. (2002) 'Uncertainty and the adoption of intelligent transport systems: a policy view', *Journal of Technology Policy and Management*, 2(1), 5–19.
- [26] Reibnitz, U. von (1998) *Scenario Techniques* (McGraw Hill, New York).
- [27] Schwartz, P. (1991) *The Art of the Long View: Planning for the Future in an Uncertain World* (Doubleday, New York).
- [28] Walker, W.A., Adnan Rahman, S. and J. Cave (2001) 'Adaptive policies, policy analysis, and policy-making', *European Journal of Operational Research* 128, 282–289.
- [29] Zuylén, H.J. and van Schaick, G.H.J. (1998) Towards a technology policy in traffic and transport' (in Dutch), *Tijdschrift Vervoerswetenschap* 3, 247–265.
- [30] Grin, J., van de Graaf, H. and Hoppe, R. (1997) *Interactive Technology Assessment* (in Dutch) (Rathenau Instituut, The Hague).
- [31] Bruijn, J.A. de and Heuvelhof, E. (2000) *Networks and Decision Making* (Lemma, Utrecht).

- [32] Jong, W.M. de (1998) *Institutional Transplantation*, Phd thesis (Eburon Publishers, Delft).
- [33] Stough, R. and Rietveld, P. (1997) 'Institutional issues in transport systems', *Transport Geography* **5**, 207–214.
- [34] Zuylen, H.J., Weber, M., Moon, D.P. and Davison, P. (1998) 'A new European approach to technology policy in traffic and transport' (in Dutch), *Tijdschrift Vervoerswetenschap* **3**, 267–287.
- [35] IAEA (The International Energy Agency) (1996) *Implementing Agreement for Electric Vehicle Technologies and Programs* (IAEA, Paris).
- [36] Weber, M. and Hoogma, R. (1998) 'Beyond national and technological styles of innovation diffusion: a dynamic perspective on cases from the energy and transport sectors', *Technology Analysis & Strategic Management* **10**, 545–566.
- [37] AssoVEL Mendrisio (1998) *Large Scale Fleet Test with Lightweight Electric Vehicle (LEVs) in Mendrisio* (2nd interim report) (Mendrisio, Switzerland).